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Investigation on System with Zirconium Hydride Moderator

N.N. Ponomarev-Stepnoi, O.N. Smirnov, R.V.Kuleva

Results of an investigation on physical characteristics of critical assemblies with zirconium hydride moderator and 90% uranium enrichment are described. The critical systems with different reflectors and without were studied. The measurements were fulfilled with assemblies of different relative concentrations $C = \frac{\rho_H}{\rho_5}$, changed within a range from 120 to 500.

1. Construction and materials of assemblies.

The physical assemblies with ZrH_n and U-235 with or without reflector were of a rectangular parallelepiped form. The assemblies had a plane heterogenous structure, fuel and moderator sheets being placed horizontally one by one. The opportunities of change of core composition, assembly dimensions, operating and safety systems were foreseen in construction. The assembly dimensions may be varied from 200 x 200 mm^2 to 500 x 600 mm^2 with height up to 800 mm. Controlling rods moved in duralumin slits 10 x 100 mm^2, with wall thickness of channel 1 mm. There were two plane rods of safety system, made of Cd, and one of steel for slow compensating, used in experiments. Fig. 1 shows a general view of the experimental arrangement.

The fuel elements of plane kind consist of a core and a coating (1). A core comprises a chemical mixture of CF_2 and U_3O_8, with 90% uranium enrichment. A coating is made of CF_2 film. The average dimensions of the fuel elements are 100 x 100 x 0.5 mm^3, with content of U_3O_8 1.85 g and CF_2 about 11.75 grams. The fuel elements were put together in the operating magazines, constitution and number of them depending on the experiment.

Two kinds of ZrH_n moderator lumps were used in the experiments. One was of rectangular parallelepiped form 50 x 50 x 10 mm^3 with density 4.84 g cm^{-3} and atomic ratio $\frac{H}{Zr} = 1.86$. Another was of a prism form with height 6 mm and length 50 mm, density 4.95 g cm^{-3} and atomic ratio $\frac{H}{Zr} = 1.91$

The lumps of Be (100x50x10 mm^3), BeO (100x50x15 mm^3) and ZrH_n were used as reflectors.

2. Experimental results.

Two series of experiments with ZrH_n systems were made. The assemblies with thick berillium reflectors were studied first, the moderator lumps of rectangular parallelepiped (atomic ratio $\frac{H}{Zr} = 1.86$) being used. Characteristics of the assemblies and critical heights measured are given in Table I (see Fig. 2 also). The thicknesses of the two side reflectors in assemblies Nºs 3,4 and 5 were 150 mm, 100 mm and 50 mm respectively. The thickness of two other reflectors was constant and equal 150 mm. In Fig. 2 a critical height and a critical mass of U-235 are plotted against the side reflector thickness. The conclusion follows from the curves, that a use of Be reflector thickness more than 120 ÷ 150 mm is not reasonable for the similar assemblies. In assemblies Nos 3 and 6 the concentration $\frac{\rho_H}{\rho_5}$ was constant and equal 280.

One fourth layer reactivity was measured for the assemblies Nos 2 and 3. "One fourth layer" comprises fuel, moderator and reflector in quantities $\frac{1}{4}$ of full content of these materials in the upper layer of an assembly. A reactivity was measured by using the graduated compensating rod. The results are summarized in Table 2.

A contribution of the upper face reflector (thickness of Be 53 mm) to the reactivity was measured the pulse neutron source being used and the result was found to be equal 0.0145 ± 0.0057. The spatial neutron distribution in the reactor as a whole and in the cell was studied by In activa-

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tion method. The results for the assembly № 1 are shown in Fig.3. The thermal neutron distribution in the fuel was measured by registration of fission products, accumulated in the fuel elements.

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Critical Parameters of Assemblies with Reflector

Table I

№	Core dimensions, mm Ax	Ay	H	Thickness of Be reflector, mm Δx	Δy	Δz	Number of fuel elements in magazine	Thickness of $ZrH_{1.86}$ mm	Dimension of plane cell, mm	U-235, kg	Temperature °C	Notes
1	312	202	548	150	150	53	5	10	15.8	$1.456^{+0.018}_{-0.018}$	18	There is upper Be reflector
2	312	202	548	150	150	-	5	10	15.8	$1.456^{+0.018}_{-0.018}$	18	K_{ef} = 0.985; subcriticality measured by pulse method
3	312	202	464	150	150	-	7	10	17.0	$1.623^{+0.020}_{-0.020}$	18	
4	312	202	493	100	150	-	7	10	16.9	$1.722^{+0.022}_{-0.022}$	18	
5	312	202	611	50	150	-	7	10	17.0	$2.121^{+0.027}_{-0.027}$	18	
6	312	202	540	150	150	-	14	20	34.0	$1.917^{+0.024}_{-0.024}$	17.5	

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Table 2

Nº assembly	Cell characteristics			"Weight" of $\frac{1}{4}$ layer $\left(\frac{\Delta K_{eff}}{K_{eff}}\right) \cdot 10^2$
	Number of fuel elements	Cell thickness, mm	Thickness of $ZrH_{1.86}$ mm	
3	7	17	10	0.23
6	14	34	20	0.31

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Table 3

Critical Parameters of Assemblies without Reflector

Nos assembly	Core dimensions, cm (parallelepiped) a	b	H	Cell characteristics: Number of fuel elements in magazine	Thickness of $ZrH_{1.91}$, mm	Cell thickness, mm	Content of U-235, kg
7	51.5	50.5	34.4	12	12	19.0	$7.077^{+0.113}_{-0.088}$
8	51.5	50.6	36.2	12	18	25.0	$5.703^{+0.087}_{-0.071}$
9	51.7	50.6	43.8	12	24	31.4	$5.782^{+0.100}_{-0.072}$
10	51.2	50.6	35.3	8	6	11.0	$8.248^{+0.136}_{-0.103}$
11	51.6	50.6	33.8	8	12	16.8	$5.349^{+0.067}_{-0.067}$
12	51.5	50.7	63.0	8	24	30.0	$6.019^{+0.075}_{-0.075}$
13	51.6	50.5	51.3	4	6	8.6	$4.904^{+0.061}_{-0.061}$
14	51.6	50.6	46.0	4	12	15.0	$4.194^{+0.052}_{-0.052}$

Table 4

№ assembly	8	11	12	13	14
Rcd	10.2	9.9	13.7	7.0	12.0
$\frac{\rho_H}{\rho_S}$	257	254	508	257	525

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Characteristics of assemblies without reflector and influence of the reflector upon the critical dimensions were studied in the second series of the experiments. Zirconium hydride moderator with atomic ratio $\frac{H}{Zr} = 1.91$ was used in the assemblies of parallelepiped form (see Table 3). The critical dimensions were determined for different concentration $\frac{\rho_H}{\rho_5}$ within a range 130 ÷ 500. The critical mass and height of an assembly are plotted against the value $\frac{\rho_H}{\rho_5}$ in Fig. 4. The material parameter depending on number of fuel elements in the layer thickness is shown in Fig. 5 for two concentrations: $\frac{\rho_H}{\rho_5} = 256$ and 516. Typical thermal neutron distribution for the layer thickness of the reactor is shown in Fig. 6. The measurements were fulfilled with the assembly № 12.

Cadmium ratio Rcd for U^{-235} in the moderator is given in Table 4. Fig.7 gives a comparison of Be, BeO and $ZrH_{1.86}$ reflector effectiveness. The gain factor 1.8 of critical mass is resulted for Be and BeO reflector with thickness 120 ÷ 150 mm in comparison with ZrH reflector.

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Literature

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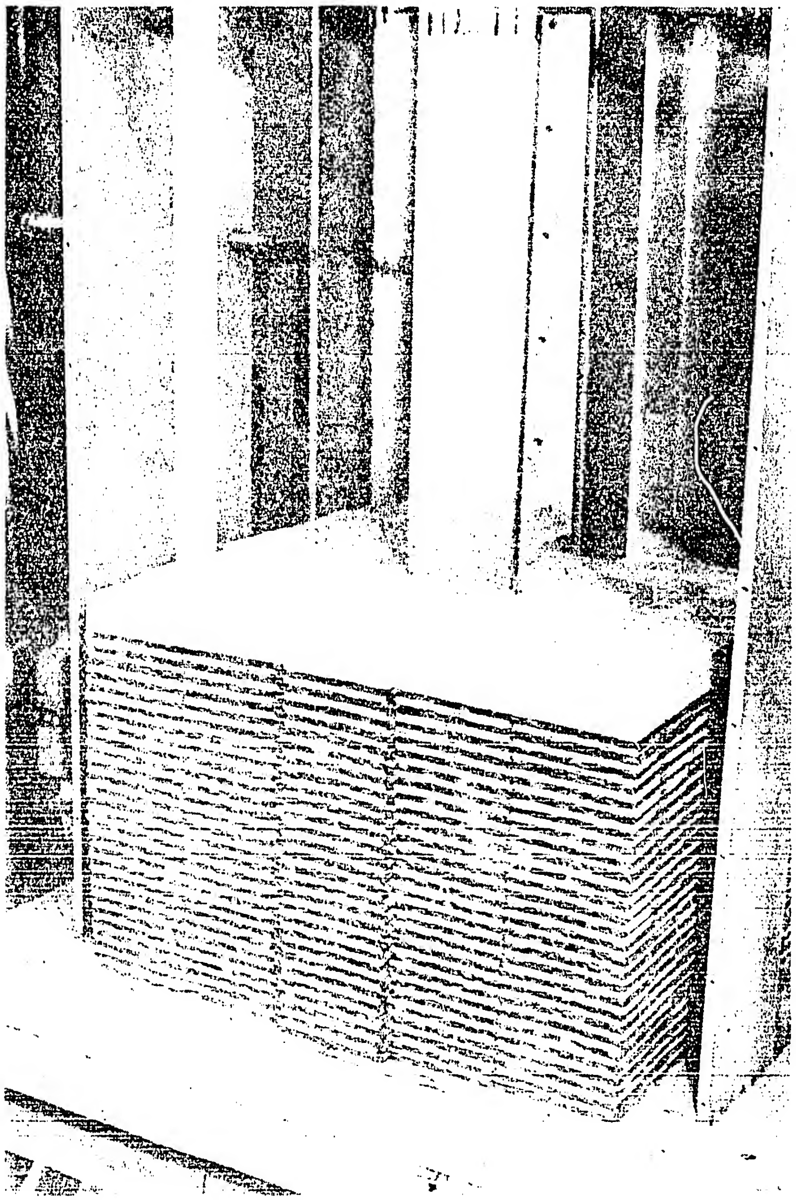

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Fig. 1.

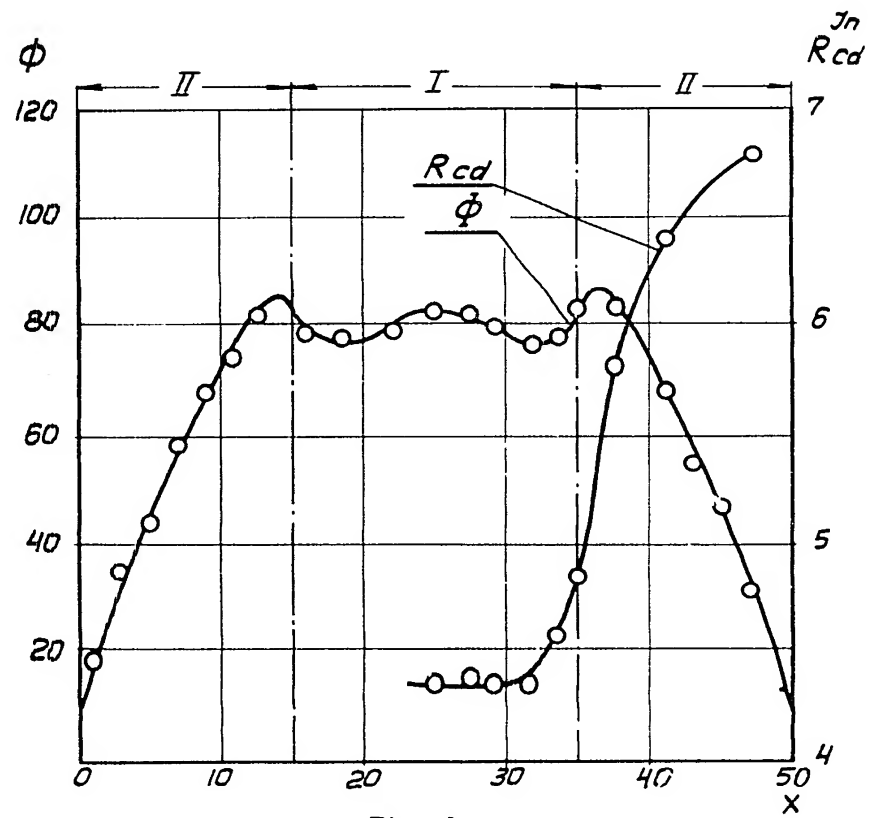

Fig. 3.

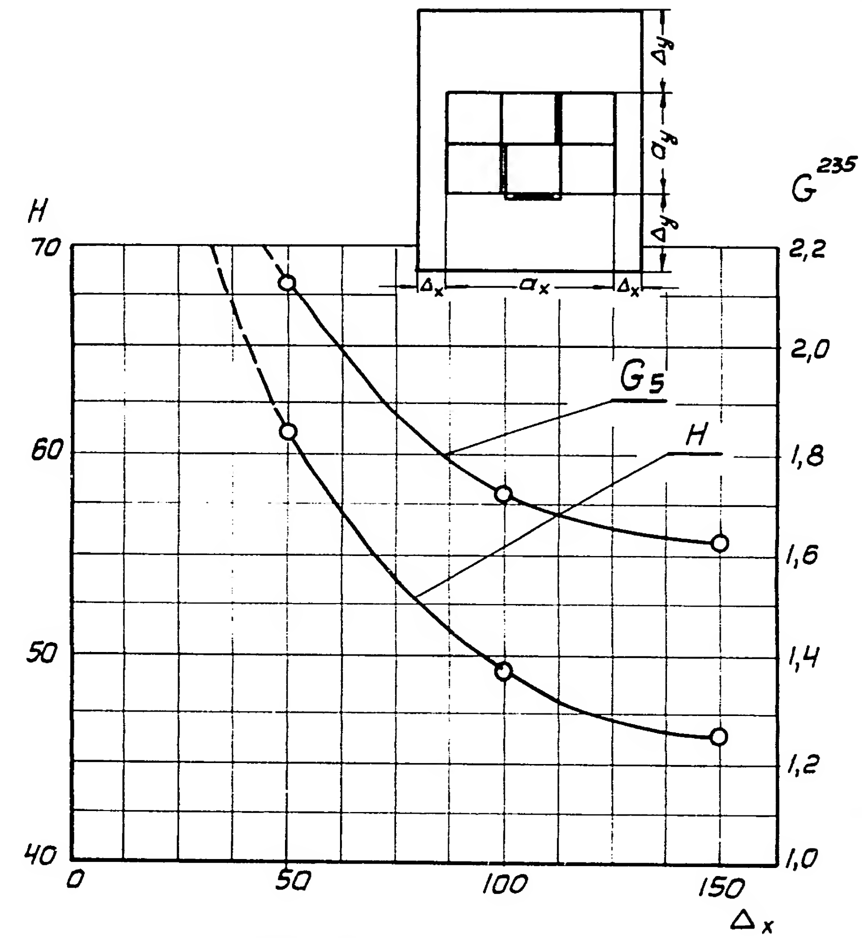

Fig. 2.

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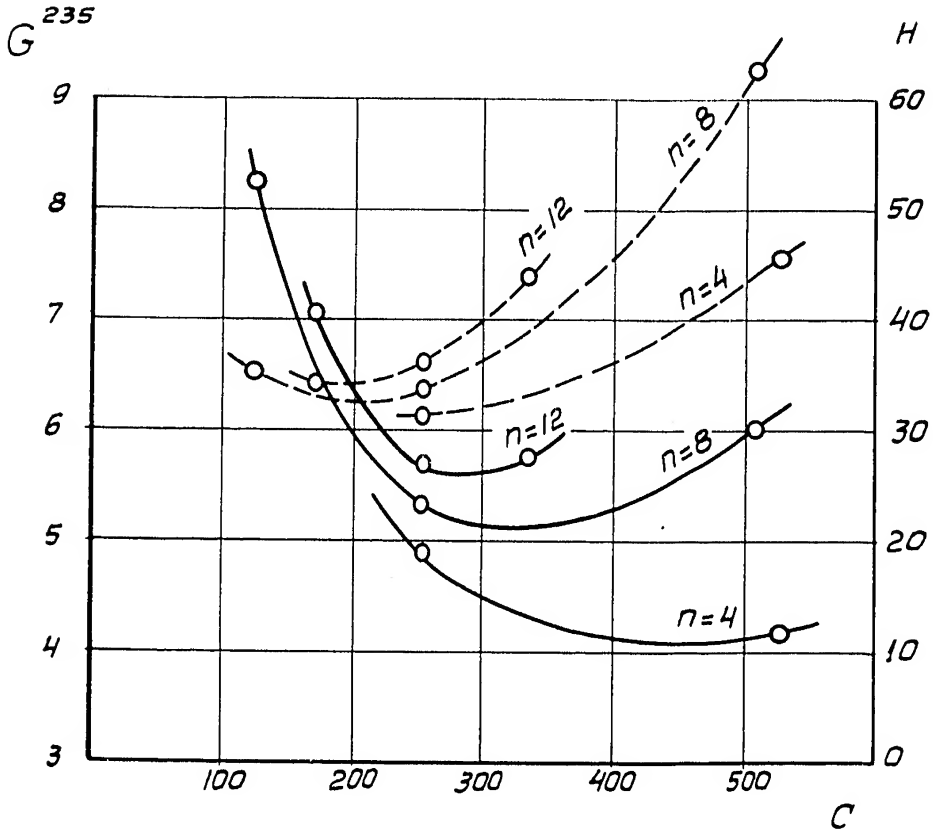

Fig. 4.

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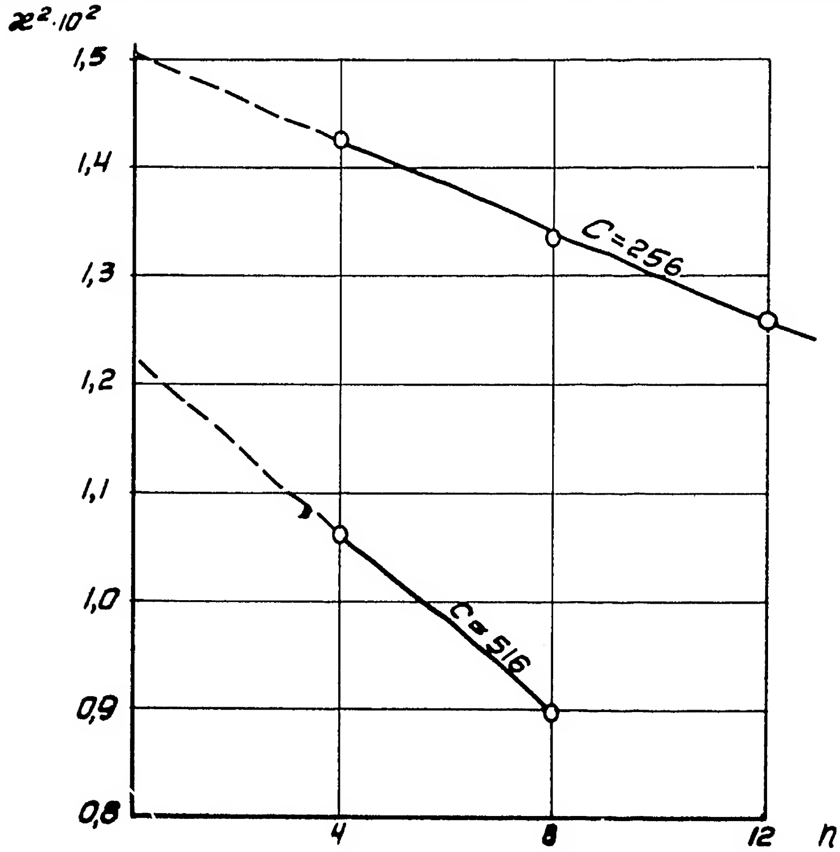

Fig. 5.

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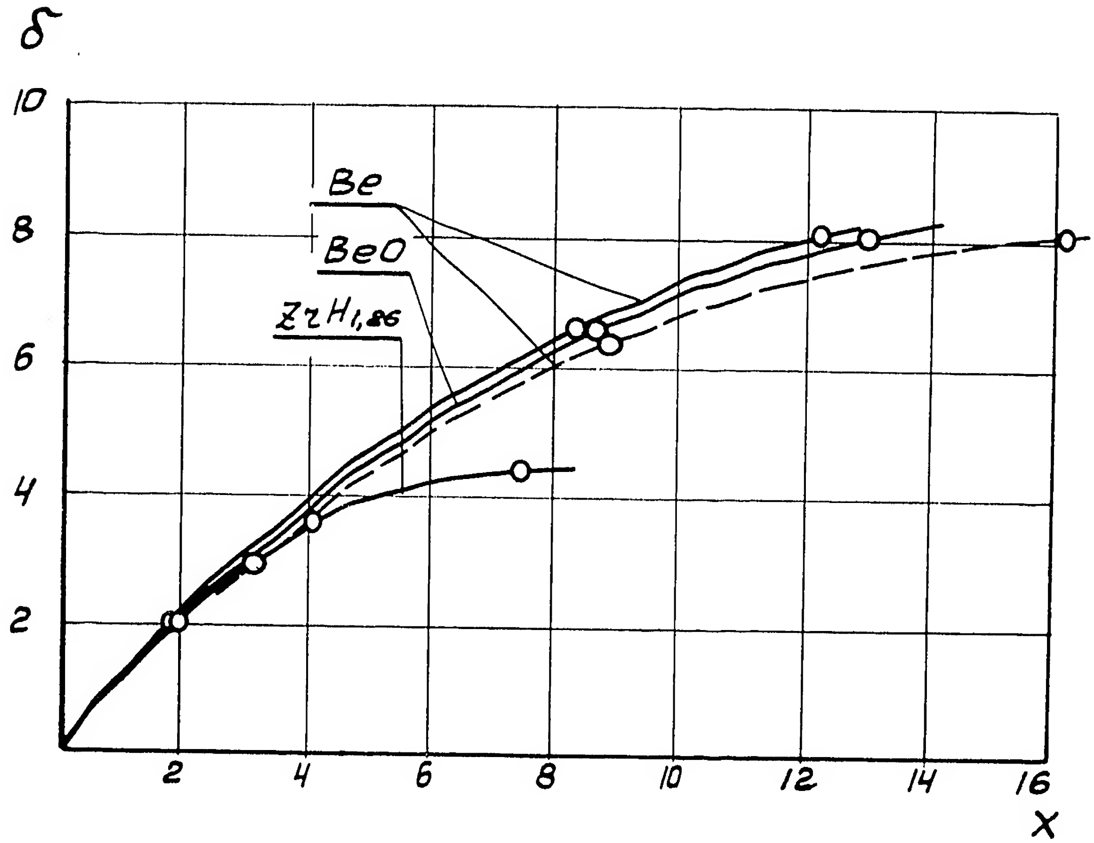

Fig. 6.

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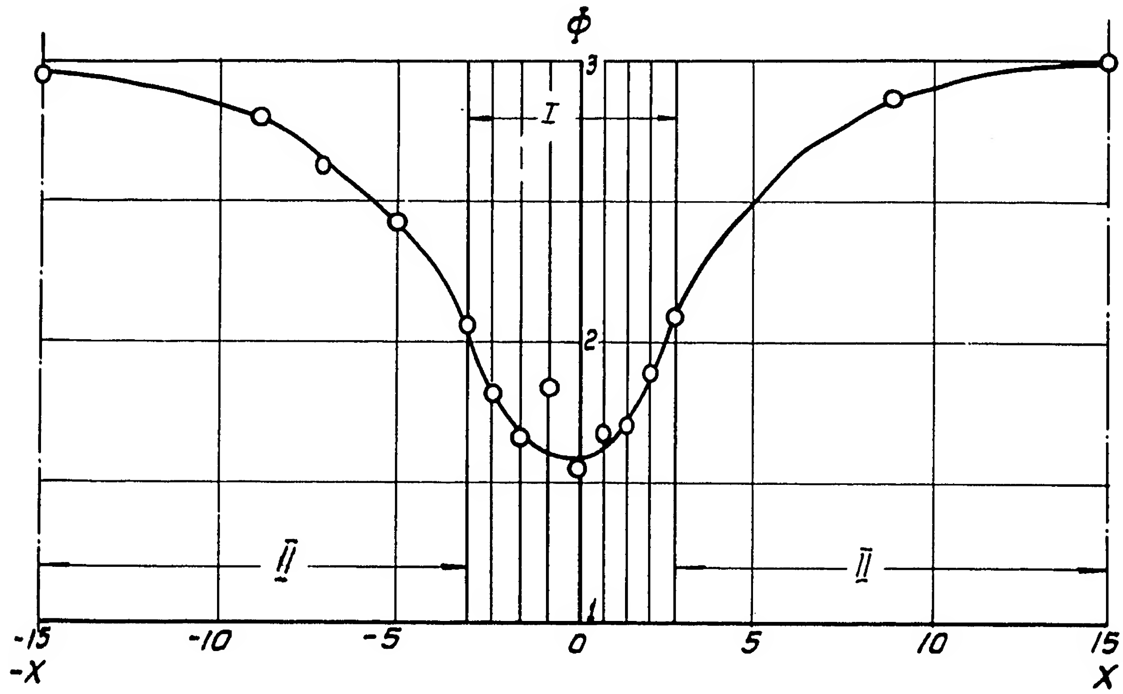

Fig. 7.

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Figure Inscriptions

Fig. 1. General view of assembly with zirconium hydride moderator

Fig. 2. Critical mass and critical height of assembly versus side reflector thickness

G^{-235} - critical mass, kg

H - critical height, cm

X - reflector thickness

Fig. 3. Thermal neutron distribution and cadmium ratio in assembly Nº1

I - core; II - reflector

ϕ - relative thermal neutron flux

R_{cd} - cadmium ratio by In

x - distance to the edge of assembly, cm

Fig. 4. Critical mass and critical height for composition $ZrH_{1.91}$-U^{235} (90%)

Solid curves - critical mass; broken curves - critical height of assembly

G^{235} - critical mass, kg

H - critical height, cm

$C = \frac{\rho_H}{\rho_S}$ - concentration

n - number of fuel elements in layer thickness

Fig. 5. Material parameter versus n - number of fuel elements in layer thickness

$æ^2$ - material parameter, $\frac{1}{cm^2}$

n - number of fuel elements

$C = \frac{\rho_H}{\rho_S}$ - concentration

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Fig. 6. Thermal neutron distribution in reactor cell. (Assembly Nº12)

I - fuel; II - moderator ($ZrH_{1.91}$)

ϕ - thermal neutron flux, relative units

x - distance from center of cell, mm

Fig. 7. Effectiveness of Be, BeO, $ZrH_{1.86}$

Solid curves - measurements with assembly Nº14;

Broken curves - assembly Nº13

δ - Physical gain factor in reactor dimensions, cm.

x - Reflector thickness, cm.

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